THE UNIVERSITY OF ALBERTA

# SEX INFLUENCES ON GROWTH AND DEVELOPMENT IN CATTLE

by

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Sex Influences on Growth and Development in Cattle" submitted by Dwight Blaine Karren in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

A study was undertaken to assess the influence sex has on the growth and development of beef cattle. Pre-weaning performance was assessed on the basis of the birth weights of 88 bull and 92 heifer calves born in the years 1967-1969 and on the weaning weights of 26 bull, 31 steer (castrated at 2 mo. of age) and 41 heifer calves in the years 1967 and 1968. Post-weaning growth and tissue development were assessed in 12 bulls, 10 steers (castrated at 2 months of age), 8 late castrates (castrated at 6 months of age) and 12 heifers from the 1967 calf crop slaughtered at three weights. These same animals were used in assessing carcass merit. The left side of the carcass was totally dissected using the technique of Butterfield and May (1965) while the right side was cut into boneless retail cuts with some modification of the method of Wellington (1953).

Bulls were heavier than heifers at birth and weaning while steers were intermediate at weaning. Bulls were superior in the per day of age production of live weight, cold carcass weight, total muscle weight and boneless retail meat but had less dissectable and retail trimmed fat. Steers and late castrates were generally intermediate but tended to resemble bulls when at lighter weights and heifers when at heavier weights.

The sexes followed similar trends of relative growth of the major tissues. With increasing weights the proportion of fat increased significantly ($P<0.01$) at the expense of muscle and bone which decreased significantly ($P<0.01$). Differences in proportions of major tissues among sexes were due to the time of the onset of the fattening

stage and the rate at which it proceeded. Heifers initiated a fattening phase at lighter weights and fattened at greater rates than did steers and late castrates which were followed by bulls. This accounted for the smaller proportion of muscle and bone and greater proportion of fat in heifers followed by steers and late castrates, and bulls.

Individual muscle groups, fat deposits and bone growth in each of the sex groups generally agreed with Hammond's theory of centripetal growth. Individual muscle groups of the limbs had slowed in growth while muscles of the abdominal wall increased. Exceptions to the centripetal theory within the musculature were an increased growth in muscles of the neck and a uniform growth of the loin.

With increasing weight the proportion of total fat lying within the forequarter, subcutaneous and kidney fat deposits increased at the expense of the hindquarter, intermuscular and body cavity fat deposits. Differences between sexes were due to the time of the onset of fattening. Bulls, with a smaller proportion of total fat had a greater proportion in the intermuscular deposits and a smaller proportion in the subcutaneous deposits than did heifers, while steers and late castrates were not significantly different from each other and were intermediate to bulls and heifers.

Bones of the extremities had slower relative growth with increasing live weight while bones more proximal showed increased relative growth. Generally steers and late castrates exceeded bulls which exceeded heifers in the proportion of long bones while bulls exceeded steers and late castrates, and heifers respectively in the proportion of flat bones.

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# INTRODUCTION

In face of changing economic values it is imperative that those associated with the production of animal protein re-evaluate their position in the future market and try to implement programs to insure their product a competitive position. This will necessitate growing animals that have a high rate of growth, efficient feed conversion and yield a desirable carcass.

Rate of gain is measured relatively easily, it is highly predictive of efficient feed conversion and consequently has been incorporated into most of the beef production testing programs. On the other hand carcass merit generally is poorly understood and therefore its application to testing programs has been slow. Much research is presently underway in an attempt to define carcass merit more meaningfully.

From the standpoint of the industry and the consumer the desirability of a carcass depends on the proportion of the major tissues; muscle, fat and bone. A desirable carcass is one that contains the maximum amount of lean meat, a minimum amount of bone and enough fat to meet consumer preferences. These characteristics are influenced by the relative growth patterns within and among the tissues.

Sex is known to influence the proportions of the major tissues through its action on relative growth. Specific research on these influences has been lacking and this lack is reflected in the procedures used in grading beef carcasses whereby heifer and bull beef is

discounted. With anticipated changes in beef grading aimed at reflecting true cutout value, it seems worthwhile that research be undertaken in an attempt to define more specifically the influence of sex on carcass merit. It was for this purpose that this study was undertaken.

# REVIEW OF LITERATURE

## I. Growth and Development

Hammond (1952) defined growth as the increase in weight until mature size is reached and development as the change in conformation and shape. This view was in agreement with earlier workers (Thompson, 1917; Huxley, 1932; and Brody, 1945) who defined growth as the increase in size while development was the change in form resulting from differential growth of constituent parts. With these definitions as a basis Pomeroy (1955) and Pálsson (1955) reviewed growth and development in farm animals. There are many methods of measuring growth: the actual weight or growth curve, the percentage increment, and the weight gained per unit of time (Minot, 1907; Hammond, 1932, 1952; Huxley, 1932; and Brody, 1945). Workers primarily interested in the practical application of growth studies usually refer to either the growth curve or to the daily weight gain (Minot, 1907). Thompson (1917) suggested that the increment per unit of time method in measuring growth rate reveals differences better than the percentage increment method.

Maynard (1947) distinguished between "true growth" and deposition of fat. On this basis growth was characterized primarily by an increase in protein, minerals and water. Fat deposition was not considered growth because it is a nutrient reserve. Pomeroy (1955) held this to be an arbitrary distinction since the subcutaneous fat of the pig is both functional and a nutrient reserve.

Developmental changes can be measured and demonstrated in various ways. They can be estimated either by body or carcass measurements or by weight of different organs, parts or tissues of the body (Pálsson, 1955). Numerous early workers (Glättli, 1894; Nathusius, 1905; Meek, 1901; Waters, 1908; Lowrey, 1911, Eckles and Swett, 1918; Brody and Ragsdale, 1924; Schmidt and Lauprecht, 1928; Hammond, 1932; and Issaachsen, 1933) engaged in growth studies of farm animals using external body measurements and liveweight changes as bases. Their work was reviewed by Pálsson (1955). Their findings suggested that at birth the head, limbs and forequarters were better developed than the hindquarters and that in postnatal life a gradient of increasing growth rate passed from the head backwards to the pelvic region. External body measurements are primarily indices of length growth of skeletal parts and therefore, though useful to elucidate general trends in conformation changes of an animal with age, they do not give any information as to the changes in weight or composition of the different parts of the body (Pálsson, 1955).

To study developmental changes Hammond (1932) developed a complete dissection technique which separated the body anatomically into its organs, parts or tissues. This method has been subsequently used by several members of his school (Pálsson, 1939, 1940; McMeekan, 1940 a, b, c, 1941; Wallace, 1948 a, b, c; and Pálsson and Vergés, 1952 a, b) and more recently with modifications by Butterfield (1963a). Once the data is available developmental changes can be demonstrated in several ways: Hammond (1932) has outlined four of these:

(i) Comparison of organs, parts of tissues as proportions of the whole.

(ii) Comparison of organs, parts or tissues as proportions of a standard organ, part or tissue.

(iii) Compare weights of organs, parts or tissues at different ages with the weight of the same organ, part or tissue at a constant age.

(iv) Compare rates of gain in weight per fixed unit of time.

Pálsson (1955) outlined the advantages and disadvantages of the various methods. Calculating percentage of the whole constituted by the various organs, parts or tissues has the disadvantage that the proportion is affected by the proportion of the other organs, parts or tissues. In the rapidly fattening animal the proportion of muscle may be decreasing even though the actual weight of muscle is increasing. In studying individual muscles, bones or fat deposits, part of the error is removed by expressing their proportion of the total muscle, bone or fat, respectively. Comparing organs, parts or tissues as a proportion of a standard organ, part or tissue removes all the error of the above method and is a satisfactory method if the standard organ, part or tissue shows little or no growth. Comparing rates of gain in weight per fixed unit of time is legitimate only when the time interval is small. The third method Pálsson (1955) believed to be a suitable method to study age changes. All the methods will give an adequate demonstration of developmental changes if the limitations are recognized and precautions are taken.

Hammond (1932) using dissection data on sheep elucidated and outlined the fundamental principles underlying developmental changes in the different anatomical regions. His theories were later confirmed by

among others, McMeekan (1940 a,b,c, 1941) in the pig and Wallace, (1948 a, b, c) and Pálsson and Vergés (1952 a, b) in the sheep. Briefly their findings indicated that developmental changes from fetus to mature animal were caused by a primary wave of growth from the cranium down to the facial parts and backwards to the lumbar region and a secondary wave of growth from the metatarsals and metacarpals to the digits and upwards along the limb and trunk to the lumbar region.

Asimilar pattern of an early onset of high growth intensity at centers near the extremities is met in each of the major tissues - muscle, fat and bone. The different tissues reach their maximum rate of growth in a definite order with age as follows: nervous tissue, bone, muscle and fat. Bone grows in length earlier than it grows in thickness. Fat accumulates in various deposits with age at different rates in the following order of increasing rate: mesenteric, kidney, intermuscular and subcutaneous.

Butterfield (1963 b) related the waves of growth to functional demands of the different areas. The newly born requires well developed leg muscles and moderate development of the dorsal trunk muscles. Development of the muscles of the abdomen is not required until the animal increases its intake of bulky food. In viewing growth on a functional basis Butterfield (1963 b) contended that there is no reason to believe that the lumbar region is late developing. Indeed his results indicated that the muscles of the loin develop uniformly throughout. The theory of a functional basis for a growth priority was also held by Fowler (1967). Fowler cited the data of Pálsson and Vergés (1952 a) for rib weights as showing that the late maturity was due to growth in the

contents of the abdominal cavity. Fowler also indicated that increased growth in the muscles of the abdominal wall of pregnant sows, as was shown by Lodge and Heap (1967) was due to increased contents of the abdominal cavity.

Whether an animal is early or late maturing depends upon the length of time taken to pass through the developmental changes, (Hammond, 1932). The rate of maturity and therefore the conformation is known to be influenced by nutritional state, breed and sex (Pálsson, 1955).

## II. Sex Influence on Growth

Male cattle are recognized as being superior to females in rate of growth and efficiency of food conversion. Generally males are heavier at birth (Botkin and Whatley, 1953; Koch and Clark, 1955; Alexander, et al., 1960; Kassab, 1964; Witt, et al., 1964; Bradley et al., 1966; Ewing et al., 1966) which indicates that prenatal growth rate of males is greater than that of females. Weaning weights are normally greater for bulls and steers than for heifers (Koch and Clark, 1955; Sewell et al., 1964; Pahnish et al., 1961; Warren et al., 1965; Bradley et al. 1966; Cundiff et al., 1966; and Sullivan, 1967). The difference in the weights being greater at weaning than at birth indicates that the male calves have had an increased growth rate over the females from birth to weaning. After reviewing the literature Turton (1962) concluded that bulls grew faster than did heifers in later growth stages.

Much information is available to indicate that bulls are generally superior to steers in growth characteristics. Steers generally

weigh less at weaning than do bulls (Warren _et_ _al_., 1965; Bailey _et_ _al_., 1966; and Cundiff _et_ _al_., 1966). While fattening for slaughter bulls have faster and more efficient gains (Klosterman _et_ _al_., 1954; Conrad _et_ _al_., 1966; Bailey _et_ _al_., 1966; Harte and Curran, 1967; and Robertson _et_ _al_., 1967).

To utilize the growth potential of bulls, delaying castration has been tried. Delaying castration theoretically allows the animal to take advantage of its growth potential as an intact male while its undesirable bull-like qualities are removed in sufficient time to produce a desirable carcass. There is much controversy as to the proper time of castration. Early castration (castration prior to four months of age) was found superior to late castration (castration at six months and later) in overall growth rate by Bakalo (1955), Champagne _et_ _al_. (1964), Thurber _et_ _al_. (1966), and Ivanov _et_ _al_. (1967). And in opposition Tyleček (1957), Richter _et_ _al_. (1960), Dikiǐ and Astahova (1962), Baǐburtcjan (1963), and Rostovcev and Švarc (1964) found late castration increased overall growth rate. Brännång (1960) and Eloff _et_ _al_. (1965) found age at castration not to alter overall growth rate.

Delaying castration may have two opposing forces. Growth rate and feed efficiency are improved while the animal is intact but castration later in life can shock the animal such that early advantages may be lost. Therefore positive results from delaying castration may rely on effectively reducing shock.

## III. Sex Influences on Development

As an animal grows from birth to maturity changes occur in its body proportions or conformation. Hammond (1932) and Pálsson and Vergés

(1952 a, b) in sheep and McMeekan (1940 a, b, c, 1941) in pigs have found these changes to be a result of differential growth gradients between the different parts and tissues of the body, taking place in a definite order throughout the growing period (Pālsson, 1955). The rate of maturing depends upon the time it takes for an animal to pass through these developmental changes (Hammond, 1932).

It is known that sex has an influence on the length of time it takes for an animal to pass through these stages and therefore has an influence on development. Hammond (1932) and Pālsson and Vergés (1952 a, b) found sex had a great influence on conformation in sheep. Their results were reviewed by Pālsson (1955). They found females to be earlier developing than males, i.e. females attained a more advanced stage of development in early life than did males. Pālsson and Vergés (1952 b) compared ewes and wethers at 9 weeks of age and at equal dressed weights of 30 lbs. and found ewes had 4.7 per cent higher dressing percentage and had all joints of the carcass, except the head and feet, proportionately further developed than the wethers. At this age the earlier maturing tissues, bone and muscle, were lighter in the ewes than in the wethers, while the latest maturing tissue, the fat, was much more fully developed in the ewes. In the latest maturing fat deposit, the subcutaneous fat, the difference between the sexes was still greater than in the earlier maturing intermuscular fat.

In the same experiment Pālsson and Vergés (1952 b) looked at differential growth within the skeleton. Skeletal parts relative to the early maturing cannons, were heavier in ewes than in wethers, the differences being greatest in the late maturing trunk bones and least

in the early maturing bones below the cannons.

At 41 weeks, after the animals of both sexes had been continuously growing at a high rate, the above situation was completely reversed with wethers, not only 48 per cent heavier than the ewes, but also reaching a proportionately much higher degree of development of the later maturing parts and tissues of the body. The wethers had a higher dressing percentage than the ewes and, relative to the weight of the brain plus eyes, all joints of the wethers were further developed than those from ewes. The difference was greatest in the late maturing trunk joints and least in the early maturing head and feet, while the neck, legs and shoulder were in an intermediate position. Wethers had all tissues more fully developed than ewes relative to the weight of the brain plus eyes in the following order of increasing difference: skeleton, muscle, intermuscular fat and subcutaneous fat. Relative to the weight of the four cannons wethers at 41 weeks had all the later maturing skeletal units further developed than ewes, while there was no difference between the sexes in the earlier maturing bones of the hind limb. The bones of the head remained relatively better developed in the ewes.

Hammond (1932) comparing the skeletal development of the ram, wether and ewe at 5 months of age, found that, relative to the four cannons all bones except those of the head and the cervical vertebrae were somewhat more fully developed in the wether than in the ewe. All skeletal parts of the ram, except the pelvis, were further developed than the wether. The difference was greatest in the skull and declined posteriorly along the axial skeleton, indicating greater retarding

effects on the anterior than on the posterior part of the body by removal of the testes. Comparison of skeletal development in rams and ewes at 4 years showed that relative to the weight of the four cannons all skeletal parts, except bones below the cannons in the fore-limb were further developed in the ram. The difference was least pronounced in the bones of the head but was greatest in the cervical vertebrae and decreased backwards to the pelvis and the hind limb, indicating the relatively greater development of the hind than the forequarter in the ewe. Pálsson (1955) reviewed the effect of sex on the external body measurements of cattle and found that sex effects the conformation of cattle on somewhat similar lines to that described in sheep. He concluded that relative to height at the withers, all body measurements were less developed in the females. The greatest differences were in the circumference of the heart girth and width and depth of chest, but least in the length of the head and width of the pelvis. Thus in general bulls exceeded females in development of late maturing parts.

Abundant evidence from carcass studies indicates that sexes differ in their rate of maturity. Generally heifers have a greater proportion of the later maturing tissue, fat, and smaller proportion of earlier maturing tissues, muscle and bone than do bulls. Within the fat deposits the later developing subcutaneous fat is more developed in heifers than in steers and least developed in bulls. Steers tend to be intermediate but as their weight increases they more resemble heifers. Thus heifers are characterized as earlier maturing than steers followed by bulls which is in agreement with Prescott and

Lamming (1964) Bailey _et al_. (1966) Bradley _et al_. (1966), and Robertson _et al_. (1967).

## IV. Possible Mechanisms for Sex Differences

The effect of sex on growth is two-fold. First, there is a direct effect of sex on growth resulting from genetic differences between males and females, and secondly an indirect effect mediated through sex hormones.

### A. Chromosomal Differences

The basic genetic difference between males and females arises from the sex chromosomes since the autosomes are practically the same in both sexes. In most mammals XX individuals are females and XY are males. The Y chromosome is necessary for male fertility (Bridges, 1916; and Stern and Hadorn, 1938) for genetic maturation (Shen, 1932) and for normal development of the testes (Pantelouris, 1967). Only one of the X chromosomes of the females is functionally active according to Lyon, (1962). Therefore males differ from females in the presence of an active Y chromosome and it may be that genes on the Y chromosome provide some stimulus for growth in the male.

It has been shown by Finlay (1925) and Zawadowsky (1931) that caponizing a cockerel produces a bird which lacks the male secondary characteristics but is larger and heavier than a normal hen. Similarly castration of a hen produces a bird which is no larger nor heavier than a normal hen. If ovaries are transplanted into castrated cockerels the resulting birds have the appearance of hens but are the same size and

weight as a normal hen. Thus in poultry the difference in growth rate between sexes is primarily a genetic difference and not due to the influence of the gonadal sex hormones. In mammals it appears as if gonadal sex hormones play a more important role.

B. Hormonal Differences

1. Male sex hormones

Male sex hormone, principally testosterone is secreted by the interstitual cells of Leydig (Paschkis *et al.*, 1967). Smaller amounts of androgenic compounds have been isolated from the adrenals of man, cattle and swine (Soffer *et al.*, 1961) from ovaries (Zander, 1958; Short, 1960) and from the placenta (Salhanick *et al.*, 1956).

The control mechanism of secretion of testosterone was reviewed by Ganong (1967). Testosterone is released from the Leydig cells of the testes in response to the pituitary gonadotropic hormone LH (luteinizing hormone, also referred to as interstitial cell stimulating hormone or ICSH). The release of LH from the pituitary is regulated by luteinizing hormone releasing factor (LHRF) from the hypothalmus. Male sex hormone has a negative feed-back on the release of LHRF from the hypothalmus.

Treatment with testosterone or comparisons between intact and castrated males indicates that it has an effect on growth and development in mammals. Exogenous sources of testosterone increased growth in cattle (Disusson *et al.*, 1950; Bogart *et al.*, 1951; Burris *et al.*, 1953) and lambs (Means *et al.*, 1953) while no response was obtained in swine (Beeson *et al.*, 1955; Whiteker *et al.*, 1959). The effect that removal of the testes has on growth has been documented previously.

Testosterone, endogenous or exogenous, promotes the development of earlier maturing tissues resulting in higher proportions of meat and bone and lower proportions of fat (Bradfield, 1967). Paschkis et al. (1967) stated that testosterone caused an increase in the total muscle mass but that the degree of response among muscles is different, which explains the larger muscles of the neck and head and the larger forequarters in the intact male. Male hormone also influences the closure of the epiphyseal cartilages and therefore prepubertal castration should result in a disproportionate increase in the length of long bones (Bradfield, 1967).

Changes in growth rate and conformation due to testosterone result from its anabolic effect. Following administration of testosterone there was increased nitrogen retention (Paschkis et al., 1967). This anabolic effect is independent of most other hormones inasmuch as it is observed in the intact, castrated, thyroidectomized adrenalectomized, hypophysectomized or alloxan treated diabetic rat (Paschkis et al., 1967). Administration of testosterone to rats stimulated RNA polymerase activity and resulted in increased RNA synthesis (Wicks and Kenney, 1964; Widnell and Tata, 1966) which is an indication of increased protein synthesis.

2. Female sex hormones

In addition to the ovaries, the adrenal gland (Beall, 1939), the placenta (Paschkis et al., 1967) and the testes (Velle, 1963) are known to secrete estrogenic compounds.

A review of the control of secretion of estrogen from the

ovaries is given by Paschkis et al. (1967). The physiological function of the ovaries is regulated by a neuroendocrine mechanism. The hypothalmus secretes FSH (follicle stimulating hormone) and LH releasing factors which control pituitary-gonadotropic activity. The secretion of these hypothalmic neurohumoral substances is influenced by a variety of external stimuli and also by a feed-back mechanism from the ovary and possibly the pituitary. FSH and LH work synergistically to cause secretion of estrogen by the thecal and granulos cells of the ovary. Prolactin in association with LH promotes the production of estrogen by the corpus luteum.

Estrogens are responsible for the growth and development of internal and external female genital organs. The effect of exogenous estrogens on the growth of domesticated animals was reviewed by Velle (1963) who concluded that stilbestrol implantations increased growth in steers and lambs and had no effect in swine. Everitt and Jury (1966 a, b) reported that ovariectomy in sheep reduced growth rate and brought about an early maturation of the carcass with a greater proportion of fat in the carcass. Ocariz (1968) attempted to elucidate the effects of estrogenic compounds on growth and development. Three month old heifers were placed in a 2 x 2 experimental design with the treatments being entire, ovariectomized, steroid, and no steroid. Ovariectomy and addition of steroid both reduced the rate of growth and increased the fat content of the carcass but differences were small. In this same study it was found that ovariectomy resulted in increased height at the withers which is in agreement with Spencer et al. (1931) and Zondek (1936) who reported that exogenous estrogen limited growth in normal females by inhibiting growth in the long bones.

Part of the influence estrogenic compounds have on growth and development may be due to its protein anabolic effect, (Kochakian, 1946). Estrodial treatment produced a rapid acceleration of synthetic processes in the rat uterus leading to accumuation of RNA and protein (Aizawa and Mueller, 1961; Ui and Mueller, 1963; Noteboom and Gorski, 1963; Talwar and Segal, 1963). Ui and Mueller (1963) suggested that estrogen stimulated the initial step in the synthesis of RNA leading to an overall stimulation of protein synthesis. More work is required to discover if these effects are unique to the female organs.

# EXPERIMENTAL

## I Objective

This research project utilizing beef cattle, serially slaughtered over a wide weight range, was designed to study:

1. the influence of sex on growth and tissue development,
2. the patterns of growth and tissue development with increasing live weight of animals, and
3. the implications of sex and live weight influences on carcass composition and retail cutout.

# II. Materials and Methods

## A. Experimental Animals

### 1. Sources and description of animals

All animals were from the University of Alberta beef research project unit at Kinsella which was outlined in general terms by Berg and McElroy (1968). Most of the animals were from the 1967 calf crop. Data from the 1968 and 1969 calf crops was limited. In 1968 calf mortality was higher than usual thus reducing the number of animals for experiment. Only the birth weights of the 1969 calf crop were available at the time of writing.

The majority of the dams of the experimental animals were two year old replacement heifers most of which were either Herefords or hybrids (Angus-Charolais-Galloway crossbreds, as mentioned in Berg and McElroy, 1968) and crosses of the 2 lines; the remainder were Brown Swiss crossbreds. All calves were sired by Shorthorn bulls.

### 2. General management

The calves were born in April and May and were nursed on their dams without creep feed until October when they were weaned. Birth weights were recorded within 48 hours of birth. From birth to weaning the calves were weighed approximately every month. In 1968 twelve each of bulls and heifers were with their dams on a confinement milking experiment and were not included in the weaning data.

It is usual practice at the research unit to castrate at weaning time. In this study those animals classed as steers were castrated in June (2 months of age) while late castrates were castrated in October (6 months of age). Castration was by the conventional-open method by which the testes and epididymes were completely removed.

After weaning the animals were transferred to a feedlot and penned in groups of ten according to sex. While in the feedlot initial, bi-monthly, and final weights were record. The feedlot ration was a self-fed concentrate plus 0.9 kg of hay per day. The concentrate was a grain mixture of rolled oats and barley (1:3) plus a pelleted supplement at a level of 5% of the concentrate mixture (Mukhoty, 1969).

Although the aim was to slaughter four animals from each of the four sex groups at each of the three predetermined weights (approximately 270 kg, 360 kg, and 450 kg) the capacity of the Meat Lab at the University of Alberta farm did not allow the schedule to be followed precisely. As a consequence some of the animals became heavier than the planned slaughter weight. In addition there were other alterations to the scheme. No animals were slaughtered at the lighter weight from the late castrate group and as well two steers from the heavier group died during the experiment.

Slaughter of most animals was performed at a local meat packing plant. The animals were trucked to the plant the morning of the kill. Slaughter was performed according to usual slaughter practice at government inspected packing plants (Mukhoty, 1969) except

that the kidney and kidney fat were not removed. The carcass was split into a right and left side and hung for 48 hours. Upon delivery to the Meat Lab the carcass was stored in a cooler at approximately 34°F.

B. Experimental Technique

1. Total dissection

The left side of each carcass was dissected using the total dissection technique of Butterfield and May (1965). Briefly it involved the quantitative separation of individual muscles, bones, and fatty tissues. The principle followed was that fat and other tissues contained no muscle but muscle contained some other tissues. Individual muscles were grouped according to the classification of Butterfield and Berg (1966b).

Fatty tissues were weighed in three categories: sub-cutaneous, intermuscular, and internal (body cavity). Loose connective tissue was weighed with fat. Tendons were weighed separately but were included with bone in the report. Precautions followed to reduce error were outlined by Mukhoty (1969).

2. Boneless retail cutting

Boneless retail cutting was done on the right side according to Wellington (1953) with some modifications:

(i) the forequarter was removed between the 11th and 12th ribs;

(ii) the cut removing the brisket and plate was run along

a line joining the shank cut and at an angle to produce a square shaped chuck;

(iii) the rib and plate were removed by cutting between the 4th and 5th ribs;

and (iv) the kidney and kidney fat were removed from the carcass. The kidney was not included in the recovered weight of the carcass but the weight of the kidney fat was.

All the bone was removed from each of the cuts and subcutaneous, intermuscular fat and internal fat were removed to a depth of approximately 5 mm.

### C. Statistical Analysis

The weights of individual muscles, bones and three different categories of fat were recorded in grams. All other weights were taken in pounds and converted to grams.

A two-way analysis of variance for weight groups and sex groups was used. To analyse the post weaning performance data, a one-way analysis of variance was used.

Where a two-way analysis of variance was used it was necessary to estimate some values. To estimate the values for late castrates at the 270 kg weight the method used was as outlined by Steel and Torrie (1960) while values for the two 450 kg steers that died were calculated from the averages of the remaining two animals.
To test the significance of the differences between several means Duncan's new multiple range test (Steel and Torrie, 1960) was used. In reporting Duncan's test any two means underscored by the same solid

line are not significantly different (P 0.05). Where the variance ratio of the two-way analysis was not significant or where the sex X weight interaction was significant a Duncan's test was not performed.

The APL system in the IBM 360/67 computer through an IBM 2741 terminal was used to analyse most of the data.

# III. Results and Discussions

## A. Performance Traits

### 1. Pre-weaning performance

#### a) Birth weights

Birth weights for the years investigated appear in Table 1. In each of the years bull calves weighed more at birth than did the heifers which is in agreement with Botkin and Whatley (1953), Koch and Clark (1955), Alexander et al.(1960), Bradley et al.(1966), Ewing et al.(1966) and Tanner et al.(1967). The average sex difference measured in the above reports was 2.4 kg while the average difference in this study was 1.6 kg. The smaller differences found in this study may have been due to the age of the dams since two year olds are themselves still growing and probably allocate smaller amounts of energy to the fetus than do mature dams. Knapp et al.(1940) reported that calves from two year old dams weighed 4.5 kg less than calves from mature dams while Koch and Clarke (1955) indicated that birth weight of calves and differences between sexes also increased with increasing age of dams. Rollins and Guilbert (1954) showed that the effect of age of dam on birth weights was smaller for the females than males. It would appear that although the male fetus has the

TABLE 1

Mean birth and weaning weights (kg) of bulls, steers and heifers born 1967-69

| | Bulls | Steers | Heifers | Var. Ratio (d.f.) |
|---|---|---|---|---|
| Birth Weight | | | | |
| 1967 | 33.7(33)[1] | | 32.5(33) | $\frac{26.58}{9.99}$(1,65)N.S. |
| 1968 | 29.5(33) | | 29.0(35) | $\frac{4.1}{17.57}$(1,66)N.S. |
| 1969 | 32.5(22) | | 29.3(24) | $\frac{114.7}{16.06}$(1,44)* |
| Weaning Weights[2] | | | | |
| 1967 | 189.2(10) | 183.0(22) | 175.0(11) | $\frac{750.06}{582.36}$(2,40)N.S. |
| 1968 | 180.9(16) | 190.6(9) | 177.8(30) | $\frac{568.14}{750.72}$(2,52)N.S. |

1 Numbers in brackets indicate number of animals.
2 180-day weights corrected for age of calf and age of dam (Berg and McElroy, 1968).
* Significant at $P < 0.05$.
N.S. Non-significant.

capacity for increased growth over the female it requires adequate nutrition to express this superiority.

b) Weaning weights

The 180-day weaning weights of the 1967 and 1968 calves corrected for age of calf and dam using the method outlined by Berg and McElroy (1968), are shown in Table 1. In both years the differences between the means were non-significant. In 1968 the results are not in agreement with 1967 results or the literature reviewed in that steers exceeded bulls in weaning weight. In the summer of 1968 there was an unusual amount of sickness and loss of condition in the calves. So as to not add to the stresses of the sickness only healthy male animals were castrated. This resulted in the higher weaning weight for steers.

Table 2 gives the differences between weaning weights of bulls, steers, and heifers for the literature reported. The smaller non-significant differences reported in this study may be attributed to the age of the dams since increasing weaning weight with increasing age of dams has been reported by Sewell *et al.* (1964), Warren *et al.* (1965) and Cundiff *et al.* (1966). Gleddie and Berg (1968) reported that average milk production during the suckling period was lower from two year old dams than from mature dams and that calf consumption and average daily gain of the calves were also lower. Creek and Nestel (1964) also showed that sex differences in weaning weights were less from two year old dams than from mature dams. They attributed the smaller differences to a greater decrease in the weight of the males

than in the females. Again the males have an increased capacity for growth but they need adequate nutrition to fulfill this capacity.

TABLE 2

Differences in weaning weights (kg) for bulls, steers, and heifers as reported in the literature

| | Bull-Steer | Bull-Heifer | Steer-Heifer | Significance Level |
|---|---|---|---|---|
| Sewell *et al*. 1964 | | | 11.0 | ** |
| Warren *et al*. 1965 | 12.1 | | 9.0 | |
| Koch and Clarke, 1955 | | 11.9 | | |
| Pahnish *et al*. 1961 | | 30.0 | | ** |
| Bradley *et al*. 1966 | | 17.0 | | * |
| Botkin and Whatley, 1953 | | 11.2 | | |
| Brinks *et al*. 1961 | | | 10.4 | |
| Field *et al*. 1964 | 10.3 | | | |
| Average | 11.2 | 19.4 | 10.6 | |

### 2. Post-weaning performance

Data on the mean weights and mean weights per day of age of the sex groups at each slaughter weight in relation to liveweight and a number of carcass constituents are presented in Table 3. Results of the analysis of variance and the multiple range test of the data are also included. Sex groups differed in age at slaughter and in

TABLE 3

Mean ages, weight and weights per day of live animal, carcass and carcass constituents for bulls, steers, late castrates and heifers at three slaughter weights

| Weight Groups | 273 kg | | | | 364 kg | | | | | 454 kg | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bull | Steer | Heifer | Var. Ratio[1] | Bull | Steer | Late Castrate | Heifer | Var. Ratio[2] | Bull | Steer | Late Castrate | Heifer | Var. Ratio[3] |
| Number of Animals | 4 | 4 | 4 | | 4 | 4 | 4 | 4 | | 4 | 2 | 4 | 4 | |
| Age At Slaughter (Days) | 287.8 | 286.2 | 328.5 | 2298.6 / 489.4 * | 348 | 369 | 411.5 | 404.2 | 3651.3 / 115.3 ** | 442.5 | 446 | 461 | 489.25 | 1811.2 / 625.8 N.S. |
| A. Weight (kg) | | | | | | | | | | | | | | |
| 1. Live Weight | 275.4 | 269.0 | 264.3 | | 388.2 | 378.5 | 401.1 | 354.4 | | 524.1 | 457.7 | 506.4 | 453.2 | |
| 2. Cold Carcass | 141.6 | 141.0 | 134.0 | | 210.0 | 203.0 | 211.8 | 193.2 | | 302.6 | 264.6 | 285.2 | 252.8 | |
| 3. Total Muscle | 93.0 | 83.6 | 80.0 | | 136.8 | 120.2 | 129.4 | 109.2 | | 194.0 | 147.8 | 162.2 | 134.4 | |
| 4. Dissectable Fat | 26.8 | 37.0 | 34.8 | | 44 | 55.6 | 59.8 | 62.2 | | 71.4 | 87.2 | 88.6 | 89.2 | |
| 5. Boneless Retail | 105.0 | 97.8 | 94.6 | | 157.2 | 137.2 | 147.6 | 128.6 | | 212.2 | 160.8 | 185.8 | 152.2 | |
| 6. Retail Trimmed Fat | 16.8 | 25.2 | 24.8 | | 31.8 | 48.8 | 48.8 | 52.4 | | 59.4 | 81.2 | 80.0 | 82.8 | |
| B. Weight Per Day of Age (kg) | | | | | | | | | | | | | | |
| 1. Live Weight | 0.96 | 0.94 | 0.80 | .0286 / .0018 ** | 1.12 | 1.03 | 0.98 | 0.87 | .0415 / .0027 ** | 1.18 | 1.03 | 1.04 | 0.98 | .0289 / .0074 * |
| 2. Cold Carcass | 0.48 | 0.50 | 0.40 | .0091 / .0006 ** | 0.60 | 0.56 | 0.52 | 0.48 | .0124 / .0011 ** | 0.68 | 0.60 | 0.58 | 0.56 | .0131 / .0022 * |
| 3. Total Muscle | 0.32 | 0.30 | 0.24 | .0074 / .0004 ** | 0.40 | 0.32 | 0.32 | 0.28 | .0098 / .0005 ** | 0.44 | 0.32 | 0.34 | 0.28 | .0150 / .0006 ** |
| 4. Dissected Fat | 0.090 | 0.130 | 0.110 | .0016 / .0001 ** | 0.125 | 0.155 | 0.145 | 0.155 | .0008 / .0002 ** | 0.164 | 0.190 | 0.176 | 0.196 | .0007 / .0006 N.S. |
| 5. Boneless Retail | 0.36 | 0.34 | 0.28 | .0052 / .0003 * | 0.44 | 0.38 | 0.36 | 0.32 | .0118 / .0006 ** | 0.48 | 0.36 | 0.38 | 0.340 | .0155 / .0006 ** |
| 6. Retail Trimmed Fat | 0.058 | 0.088 | 0.076 | .0008 / .0001 ** | 0.092 | 0.132 | 0.118 | 0.128 | .0014 / .0001 ** | 0.136 | 0.180 | 0.164 | 0.180 | .0016 / .0006 N.S. |

1 2 and 9 degrees of freedom.
2 3 and 12 degrees of freedom.
3 3 and 10 degrees of freedom.
** Variance ratio significant at $P < .01$.
* Variance ratio significant at $P < .05$.
N.S. Variance ratio non-significant.

weight at slaughter, therefore comparisons were made on a per day basis to minimize effects of age or weight on the results. In ranking the means, a greater production of liveweight per day of age, cold carcass per day of age, total muscle weight per day of age, total boneless reta weight per day of age was considered superior as was a decreased amount of dissected fat or trimmed fat per day of age.

Bulls were significantly ($P < 0.05$) superior to heifers in all the production parameters considered except at the heaviest weight where there were no significant differences between any of the sex groups for dissected or trimmed fat per day of age. As a general trend steers and late castrates were intermediate to bulls and heifers. Where comparisons were made there were no significant differences between the steers and late castrates.

At the intermediate weight range steers seemed to resemble bulls more closely in production traits while at the heavier weights steers and late castrates more closely resembled heifers. This is to be expected if heifers are considered early maturing followed by steers and late castrates and finally bulls.

These results agree with other reports in the literature. Field _et al_. (1964) reported that bulls exceeded steers in liveweight per day of age, cold carcass weight per day of age, estimated retail yield per day of age, and gain per day on feed while steers exceeded bulls in the production of retail trimmable fat per day of age. Bailey and Hironaka (1969) indicated that bulls had a greater final weight per day of age and a greater estimated separable muscle per

day of age than did early and late castrates. Berg (1969) reported steers exceeded heifers by 0.14 pounds of lean meat produced per day of age and bulls exceeded steers by 0.19 pounds. Bradley et al. (1966) reported steers were significantly ($P < 0.05$) greater than heifers in the production of cold carcass weight per day of age.

3. Boneless retail cuts

Table 4 gives the proportions of the cold carcass constituted by total boneless cuts, trimmed fat and various retail cuts at three slaughter weights and for four sex groups.

With increasing weight the proportion of the carcass in total boneless cuts and in the "higher priced cuts" (loin, round and ribs) generally decreased which is in agreement with Nichols et al. (1964), while the proportion of "cheaper cuts" (brisket and flank) generally increased, in agreement with Luitingh (1962). Exceptions to this general scheme were a decrease in shank, which unlike the other "cheaper priced" cuts is not prone to fattening, and an increase in chuck which has a high impetus to fatten. Also, it will be seen later (Table 7) that the muscles that make up the chuck are late maturing and would thus tend to increase its proportion at heavier weights.

Bulls had a larger proportion of total boneless cuts and a smaller proportion of trimmable fat than did steers and heifers respectively. This trend was also followed in each of the individual retail cuts. Although there was a difference in designation of cuts, the literature seems to agree with these results. Tanner et al. (1967)

TABLE 4

Cold carcass weight (kg) and proportions (%) of boneless, closely trimmed retail cuts from three weight groups and four sex groups of slaughter animals

| | Weight Groups | | | | | Sex Groups | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 273 kg | 364 kg | 454 kg | Var.[1] Ratio | | Bulls | Steers | Late Castrates | Heifers | Var.[2] Ratio | | Sex X Weight Interaction |
| Cold Carcass Wt. | 138.9 | 204.6 | 276.3 | | | 218.1 | 203.1 | 248.5 | 193.3 | | | |
| Total Boneless Cuts | 69.7 | 66.1 | 61.8 | 246.64 / 3.36 | ** | 71.1 | 64.0 | 65.3 | 63.0 | 160.05 / 3.36 | ** | N.S. |
| Total Trimmed Fat | 15.7 | 21.2 | 26.8 | 488.21 / 4.45 | ** | 15.1 | 23.5 | 21.4 | 25.0 | 226.86 / 4.46 | ** | N.S. |
| Hindquarter | 50.7 | 50.9 | 50.0 | 3.96 / .95 | * | 49.3 | 51.1 | 50.6 | 51.1 | 8.54 / .95 | ** | N.S. |
| Flank | 2.8 | 2.7 | 2.9 | 0.29 / 0.15 | N.S. | 3.0 | 2.5 | 2.9 | 2.8 | 0.42 / 0.15 | N.S. | * |
| Loin | 14.5 | 12.1 | 11.1 | 49.96 / 1.56 | ** | 12.9 | 12.1 | 12.5 | 12.8 | 1.38 / 1.56 | N.S. | N.S. |
| Round | 16.2 | 16.7 | 15.1 | 11.03 / 1.24 | ** | 17.2 | 15.9 | 16.1 | 14.8 | 11.08 / 1.24 | ** | N.S. |
| Forequarter | 49.3 | 49.1 | 50.1 | 4.20 / .95 | * | 50.7 | 48.9 | 49.4 | 48.9 | 8.50 / 0.95 | ** | N.S. |
| Shank | 3.1 | 2.3 | 2.3 | 3.00 / 0.17 | ** | 2.7 | 2.3 | 2.9 | 2.3 | 0.92 / 0.17 | ** | N.S. |
| Brisket | 7.1 | 7.0 | 7.6 | 1.20 / 0.51 | N.S. | 7.6 | 6.8 | 7.7 | 6.9 | 2.74 / 0.51 | ** | N.S. |
| Ribs | 9.0 | 7.0 | 6.4 | 29.64 / 0.46 | ** | 8.1 | 7.4 | 7.2 | 7.1 | 2.43 / 0.46 | ** | N.S. |
| Chuck | 15.3 | 17.3 | 15.5 | 18.47 / 0.70 | ** | 18.5 | 15.5 | 15.0 | 15.1 | 32.9 / 0.70 | ** | ** |

1 2 and 31 degrees of freedom.
2 3 and 31 degrees of freedom.
** Variance ratio significant at $P < .01$.
* Variance ratio significant at $P < .05$.
N.S. Variance ratio non-significant.

indicated that bulls exceeded steers in percentage cutability and percentage round. Field *et al*. (1964) found bulls to have a significantly greater proportion of estimated retail cuts, chuck, round, loin, sirloin tip than did steers while difference in ribs were non-significant. Nichols *et al*. (1964) showed bulls to have a significantly greater proportion of desirable cuts due to a significantly ($P < 0.01$) greater proportion of round while the differences between chuck, loin and ribs were non-significant.

## B. Growth of Major Tissues

Table 5 shows the weight of muscle, bone and fat in the carcass as well as their proportion of the cold carcass weight at the three slaughter weights and among the four sex groups.

Absolute growth of the major tissues over the weights studied was as expected; muscle, fat and bone each increased in weight. The magnitude of the increases were different; the largest percentage increase in total weight was shown by fat (144.5%) followed by muscle (83.6%) and bone (55%). It follows then as weight increased in the live animal the proportions of the tissues changed. It can be seen in Table 5 that as the weight of the live animal increased the proportion of fat increased significantly ($P < 0.01$) at the expense of muscle and bone which decreased significantly ($P < 0.01$).

Bulls at heavier weights than steers and heifers had a significantly ($P < 0.05$) greater amount of muscle and bone and a significantly ($P < 0.05$) smaller amount of fat (Table 5). Similarly

TABLE 5

Two-way analysis of variance on weight and sex for total weight of tissue and tissue proportion of cold carcass weight

| | Weight Group | | | Var.[1] Ratio | Sex Group | | | | Var.[2] Ratio | Sex X Weight Interaction |
|---|---|---|---|---|---|---|---|---|---|---|
| | 273 kg | 364 kg | 454 kg | | Bulls | Steers | Late Castrate | Heifer | | |
| Number of Animals | 12 | 16 | 14 | | 12 | | 8 | 12 | | |
| Age (Days) | 300.8 | 383.2 | 459.8 | | 360.6 | 365.9 | 450.5 | 397.9 | | |
| Live Weight (kg) | 269.5 | 380.6 | 485.4 | | 395.9 | 368.5 | 453.8 | 357.3 | | |
| Cold Carcass Weight (kg) | 138.9 | 204.6 | 276.3 | | 218.1 | 203.1 | 248.5 | 193.3 | | |
| 1. Muscle (kg) | 86.9 | 123.9 | 159.6 | $\frac{21187.12}{36.04}$ ** | 141.3 | 117.2 | 127.5 | 107.9 | $\frac{2467.32}{36.04}$ ** | ** |
| 2. Bone (kg) | 20.9 | 26.7 | 32.4 | $\frac{531.32}{2.36}$ ** | 29.3 | 26.1 | 28.0 | 23.2 | $\frac{84.00}{2.36}$ ** | ** |
| 3. Fat (kg) | 34.4 | 55.4 | 84.1 | $\frac{9996.00}{43.64}$ ** | 47.5 | 59.9 | 62.4 | 62.1 | $\frac{601.76}{43.64}$ ** | N.S. |
| 4. Percent Muscle | 61.5 | 60.5 | 58.0 | $\frac{53.06}{4.88}$ ** | 64.9 | 58.1 | 59.8 | 57.1 | $\frac{145.36}{4.88}$ ** | N.S. |
| 5. Percent Bone | 14.8 | 13.0 | 11.8 | $\frac{35.78}{0.75}$ ** | 13.8 | 13.2 | 13.3 | 12.4 | $\frac{3.70}{0.75}$ ** | * |
| 6. Percent Fat | 23.9 | 27.2 | 30.8 | $\frac{186.06}{5.20}$ ** | 21.1 | 28.9 | 28.0 | 31.2 | $\frac{228.08}{5.20}$ ** | N.S. |

1 2 and 31 degrees of freedom.
2 3 and 31 degrees of freedom.
** Variance ratio significant at $P < .01$.
* Variance ratio significant at $P < .05$.
N.S. Variance ratio non-significant.

heifers at lighter weights than steers had slightly larger amounts of fat. To illustrate this more appropriately a one-way analysis of covariance was performed which indicated at similar weights of muscle plus bone heifers had a greater amount of fat than did late castrates followed by steers and bulls respectively. Bulls had a significantly ($P<0.05$) greater proportion of muscle and bone and a smaller proportion of fat than did the other sex groups. Steers and late castrates were intermediate to bulls and heifers but more closely resembled heifers in their body composition.

These results suggest that when comparing carcass composition of different sexes weight is an important variable to consider. At equal weights the proportions of the major tissues are quite different because the sex groups initiate fattening at different weights; heifers would have a greater proportion of fat than steers and steers a greater proportion than bulls. At equal proportions of fat in the carcass the sex groups should be very similar in composition.

This general pattern of tissue deposition among sex groups is supported by the results of other workers (Prescott and Lamming, 1964; Bailey et al. 1966; Bradley et al. 1966; Robertson et al. 1967; and Berg, 1969).

Observations of differences in proportions of the major tissues between sexes do not indicate how these differences may have arisen. Were they due to a decrease in the impetus for muscle and bone growth or an increase in the impetus for fat deposition? To attempt to answer this problem the relationship of muscle, fat and bone to total muscle plus bone was calculated on a double logarithmic scale. The regression

TABLE 6

Growth coefficients, standard error of b's, and significant levels of differences among sexes for the weight of muscle,fat and bone regressed in the weight on muscle plus bone

| | Bulls | Steer | Late Castrate | Heifers | Sign.[1] Level of Regression |
|---|---|---|---|---|---|
| Number Animals | 12 | 10 | 8 | 12 | |
| Cold Carcass Weight (kg) | 218.1 | 203.1 | 248.5 | 193.3 | |
| Growth Coefficients (b) | | | | | |
| 1. Muscle | 1.06 | 1.05 | 1.01 | 1.04 | 0.21 N.S. |
| S.E. of b | 0.03 | 0.02 | 0.01 | 0.02 | |
| 2. Fat | 1.37 | 1.46 | 1.43 | 1.84 | 1.60 N.S. |
| S.E. of b | 0.17 | 0.17 | 0.41 | 0.15 | |
| 3. Bone | 0.72 | 0.77 | 0.97 | 0.84 | 0.78 N.S. |
| S.E. of b | 0.07 | 0.08 | 0.05 | 0.11 | |

1 4 and 42 degrees of freedom.

N.S. Non-significant.

coefficients (b) indicate the proportionate growth of muscle, fat and bone to muscle plus bone and are referred to as growth coefficients (Huxley, 1932; and Berg and Butterfield, 1966b). The regressions, standard errors and the significance of the differences of regressions among sex groups are given in Table 6.

Numbers are rather limited in each group and although statistically significant results were not achieved for growth coefficient differences among the sex groups, the trends agree with Mukhoty (1969) who found that the growth impetus for muscle ranked bulls over steers and steers over heifers. The reverse order existed for growth coefficients for bone. The largest differences were among the growth coefficients for fat of which heifers had the largest coefficient followed by steers, late castrates and bulls in that order. This would suggest that growth of muscle is similar in each of the groups and that changes result from differences in impetus for fat deposition.

## C. Differential Growth Within the Major Tissues

### 1. Individual muscle groups

Table 7 gives the mean proportion of total muscle for each of the nine muscle groups as defined by Butterfield and Berg, (1966a) by sex and weight groups. Changes in proportion of muscle in each of the nine muscle groups over the growing period in this study generally supports the theories of Hammond as reported by Pálsson (1955) in that muscles of the limbs were growing at a slower rate than total muscle and muscles of the abdominal wall were growing at a rate faster than total

TABLE 7

Growth of muscle determined at three slaughter weights and comparative growth in the sex groups (muscle group as a percentage of total carcass muscle)

| | Weight Group | | | | Sex Group | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 273 kg | 363 kg | 454 kg | Var. Ratio[1] | Bull | Steer | Late Castrate | Heifer | Var. Ratio[2] | Sex X Weight Interaction |
| 1. Proximal Pelvic Limb | 30.4 | 29.3 | 28.6 | 13.10/0.54 ** | 28.4 | 30.0 | 29.6 | 29.6 | 5.27/0.54 ** | N.S. |
| 2. Distal Pelvic Limb | 4.8 | 4.2 | 4.0 | 2.85/0.03 ** | 4.1 | 4.4 | 4.4 | 4.4 | 0.22/0.03 ** | N.S. |
| 3. Surrounding Spinal Column | 12.5 | 12.6 | 12.5 | 0.08/0.20 N.S. | 12.3 | 12.3 | 12.5 | 13.1 | 1.16/0.20 ** | N.S. |
| 4. Abdominal Wall | 10.5 | 10.9 | 11.6 | 5.37/0.41 ** | 10.7 | 10.8 | 11.0 | 11.4 | 1.17/0.41 N.S. | N.S. |
| 5. Proximal Thoracic Limb | 12.0 | 12.0 | 11.9 | 0.06/0.12 N.S. | 12.1 | 12.2 | 11.9 | 11.8 | 0.40/0.12 * | N.S. |
| 6. Distal Thoracic Limb | 2.5 | 2.3 | 2.2 | 0.40/0.01 ** | 2.3 | 2.4 | 2.4 | 2.3 | 0.05/0.01 ** | N.S. |
| 7. Thorax to Thoracic Limb | 9.4 | 10.1 | 10.2 | 2.51/0.13 ** | 10.2 | 10.0 | 9.6 | 9.9 | 0.65/0.13 ** | N.S. |
| 8. Neck to Thoracic Limb | 4.7 | 5.1 | 5.5 | 2.98/0.17 ** | 5.4 | 4.9 | 5.2 | 4.9 | 0.79/0.17 ** | N.S. |
| 9. Neck to Thorax | 10.7 | 10.8 | 11.0 | 0.36/0.18 N.S. | 11.9 | 10.4 | 10.6 | 10.4 | 5.69/1.19 ** | * |
| Percent Muscle In Carcass | 61.5 | 60.5 | 58.0 | | 64.93 | 58.12 | 59.78 | 57.10 | | |

1 2 and 31 degrees of freedom.
2 3 and 31 degrees of freedom.
** Variance ratio significant at $P < .01$.
* Variance ratio significant at $P < .05$.
N.S. Variance ratio non-significant.

muscle. The exceptions to Hammond's theory were that the muscles of the loin (muscle group 3) grew uniformly throughout which is in agreement with Butterfield (1963b) and the muscles of the neck (muscle groups 8 & 9) grew at a rate faster than total muscle indicating that region was late maturing.

Bulls had a greater proportion of muscle of the neck and shoulders (muscle groups 5, 6, 7, 8 and 9) than did heifers, which agrees with the work of Pálsson (1955). Consequently bulls had a smaller proportion of the other muscle groups. Steers and late castrates tended to be intermediate to bulls and heifers which agrees with Hammond (1932).

Relative muscle growth was studied by Butterfield and Berg (1966b) using data from anatomical dissection of slaughtered animals of various ages, breeds and weights. Comparison of their results with this experiment is made in Table 8. When differences in ages are taken into account there seems to be good agreement between the two studies. Butterfield and Berg (1966a) indicated that most muscles showing diphasic growth patterns finish their initial stage of differential growth early in postnatal life. Since slaughter of animals in this study took place at older ages diphasic growth patterns would not be apparent. The only muscle group that was not in agreement was group 4. This may be attributed to the variety of management practices represented in the data of Butterfield and Berg and a possible confounding of age at slaughter with manangement. The animals in the present study were on a uniform heavy-grain ration and muscle group 4 showed a steady rate of increase in percentage of total muscle.

TABLE 8

Muscle group growth; comparison of results obtained in this experiment with those obtained by Butterfield and Berg (1966b)

| Muscle Group | Growth Coefficient "b" (Butterfield & Berg 1966b) | Results of this experiment |
|---|---|---|
| 1. Proximal Pelvic Limb | High-average or low | Low |
| 2. Distal Pelvic Limb | Low | Low |
| 3. Surrounding Spinal Column | Average | Average |
| 4. Abdominal Wall | High-average or low | High |
| 5. Proximal Thoracic Limb | Low-average | Average |
| 6. Distal Thoracic Limb | Low-average or low | Low |
| 7. Thorax to Thoracic Limb | High | High |
| 8. Neck to Thoracic Limb | Average-high | High |
| 9. Neck to Thorax | Low-average | Average |

2. Fat deposits

In Table 9 are presented the proportions of the total fat obtained from the various fat deposits for the three weight and four sex groups. Proportions do not always sum to 100% because of the estimation of some of the missing values as outlined earlier.

The proportion of total fat in the cold carcass increased with increasing weight of the animals. At all three weights the percentage of fat in the hindquarter of the carcass was greater than in the front but at the heavier liveweights the differences between the two decreased. In the hindquarter subcutaneous deposits constituted a greater proportion than did other deposits while in the front the greater proportion was in the intermuscular deposits. In both hind and front quarters as total percentage of fat increased the proportion of subcutaneous fat increased significantly at the expense of intermuscular and body cavity deposits. These results are generally in agreement with the theories of Hammond (Pālsson, 1955) and the work of Schön and Schön (1964).

Differences between sexes in the proportion of fat in the various deposits may be explained by the pattern outlined above. Bulls, with a lower proportion of total fat had a significantly greater proportion of intermuscular and body cavity fat and a significantly smaller proportion of subcutaneous fat than did heifers while steers and late castrates were generally intermediate. These results are similar to those of Schön and Schön (1964). Brown _et al_. (1962), Field _et al_. (1964), Prescott and Lamming (1964), Robertson _et al_. 1967 and Bailey and Hironaka (1969)have shown that steers have a greater depth

TABLE 9

Proportion of total fat in various fat deposits for three slaughter weights and four sex groups

| | Weight Group | | | | Sex Group | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 273 kg | 363 kg | 454 kg | Var.[1] Ratio | Bull | Steer | Late Castrate | Heifer | Var.[2] Ratio | Sex X Weight Interaction |
| Hindquarter | 56.4 | 54.0 | 53.3 | 41.75/33.54 N.S. | 55.2 | 54.3 | 53.3 | 55.6 | 12.91/33.54 N.S. | N.S. |
| Subcutaneous | 37.6 | 41.7 | 47.9 | 431.05/22.52 ** | 38.4 | 41.6 | 44.0 | 46.0 | 120.89/22.52 ** | N.S. |
| Intermuscular | 32.8 | 26.3 | 23.2 | 382.93/13.69 ** | 31.2 | 27.9 | 26.4 | 24.2 | 103.75/13.69 ** | N.S. |
| Body Cavity | 12.4 | 12.1 | 9.7 | 36.82/10.22 * | 12.7 | 10.2 | 11.8 | 10.9 | 14.36/10.22 N.S. | N.S. |
| Kidney | 16.8 | 20.6 | 19.2 | 58.25/11.25 * | 18.4 | 20.3 | 17.5 | 19.1 | 16.79/11.25 N.S. | N.S. |
| Forequarter | 46.2 | 45.8 | 46.9 | 5.45/5.35 N.S. | 44.8 | 45.7 | 47.2 | 47.4 | 18.48/5.35 * | N.S. |
| Subcutaneous | 28.4 | 29.8 | 34.2 | 146.53[3]/14.08 ** | 28.6 | 30.7 | 29.8 | 34.1 | 68.22[4]/14.08 ** | N.S. |
| Intermuscular | 62.0 | 60.3 | 57.0 | 107.23[3]/12.40 ** | 61.2 | 61.2 | 59.7 | 57.0 | 47.83[4]/12.4 * | N.S. |
| Body Cavity | 9.4 | 9.9 | 9.0 | 2.65[3]/1.96 N.S. | 10.2 | 8.4 | 10.2 | 8.9 | 9.89[4]/1.96 ** | N.S. |
| Percent Fat In Carcass | 23.9 | 27.2 | 30.8 | | 21.1 | 28.9 | 28.0 | 31.2 | | |

1 2 and 31 degrees of freedom.
2 3 and 31 degrees of freedom.
3 2 and 30 degrees of freedom.
4 3 and 30 degrees of freedom.
** Variance ratio significant at $P < .01$.
* Variance ratio significant at $P < .05$.
N.S. Variance ratio non-significant.

of subcutaneous fat cover over the longissimus dorsi than did bulls. Greater amounts of kidney fat were found in steers than in bulls by Field et al. (1964), Prescott and Lamming (1964) and Robertson et al. (1967).

### 3. Individual bones

Data for growth of bone were treated in a similar manner to muscle and fat and results are reported in Table 10. Weights of individual bones and bone groups are expressed as a proportion of total bone.

There appears to be good agreement between the results of this study and the growth patterns proposed by Hammond's school (Pálsson, 1955). Bones of the extremities; cervical vertebrae, radius and ulna, humerus, tibia, and femur were tending to decrease in percentage, that is growing at a rate less than total bone as weight increased, while the ribs, scapula and pelvis increased their rate above that of total bone. One exception to the theory was that the lumbar vertebrae grew uniformly throughout which is in agreement with Walker (1963).

It is interesting to note that growth of muscle groups (Table 7) paralleled bone growth. In general muscles associated with the long bones, were found to decrease as a proportion of total muscle. similarly the muscles associated with the ribs, the muscles of the abdomen and those of the thorax to thoracic limb increased in proportion.

TABLE 10

Growth of individual bones and bone groups as illustrated by percentage of total bone at three weights and four sex groups

| | Weight Group | | | | Sex Group | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 273 kg | 364 kg | 454 kg | Var. Ratio[1] | Bull | Steer | Late Castrates | Heifer | Var. Ratio[2] | Sex X Weight Interaction |
| Radius and Ulna | 6.5 | 6.5 | 6.3 | $\frac{0.19}{0.08}$ N.S. | 6.2 | 6.5 | 6.5 | 6.5 | $\frac{0.33}{0.08}$ * | N.S. |
| Humerus | 8.7 | 8.6 | 8.5 | $\frac{0.31}{0.12}$ N.S. | 8.5 | 8.8 | 8.8 | 8.3 | $\frac{0.68}{0.12}$ ** | N.S. |
| Tibia | 7.5 | 7.4 | 7.0 | $\frac{1.17}{0.13}$ ** | 7.0 | 7.4 | 7.5 | 7.3 | $\frac{0.67}{0.13}$ ** | N.S. |
| Femur | 11.7 | 11.8 | 11.0 | $\frac{2.59}{0.29}$ ** | 11.2 | 11.6 | 11.9 | 11.5 | $\frac{0.93}{0.29}$ * | N.S. |
| Scapula | 5.1 | 5.3 | 5.5 | $\frac{0.68}{0.07}$ ** | 5.5 | 5.3 | 5.2 | 5.3 | $\frac{0.17}{0.07}$ N.S. | N.S. |
| Pelvis | 11.4 | 11.8 | 11.9 | $\frac{1.27}{0.67}$ N.S. | 11.4 | 11.1 | 11.5 | 12.6 | $\frac{5.30}{0.67}$ ** | N.S. |
| Ribs | 14.1 | 15.6 | 16.7 | $\frac{26.64}{0.72}$ N.S. | 15.7 | 15.0 | 15.1 | 16.2 | $\frac{3.76}{0.72}$ ** | N.S. |
| Cervical Vertebrae | 6.5 | 6.0 | 5.9 | $\frac{1.68}{0.36}$ * | 6.2 | 5.9 | 6.4 | 6.0 | $\frac{0.55}{0.36}$ N.S. | N.S. |
| Lumbar Vertebrae | 4.8 | 4.7 | 5.3 | $\frac{1.59}{0.93}$ N.S. | 5.0 | 5.0 | 5.0 | 4.7 | $\frac{0.26}{0.93}$ N.S. | N.S. |
| Thoracic Vertebrae | 9.0 | 8.7 | 8.9 | $\frac{0.50}{1.05}$ N.S. | 9.0 | 9.5 | 8.6 | 8.4 | $\frac{2.61}{1.05}$ N.S. | N.S. |
| Percent Bone in Carcass | 14.8 | 13.0 | 11.8 | | 13.8 | 13.2 | 13.3 | 12.5 | | N.S. |

1 2 and 31 degrees of freedom.
2 3 and 31 degrees of freedom.
** Variance ratio significant at P <.01.
* Variance ratio significant at P <.05.
N.S. Variance ratio non-significant.

Generally steers and late castrates exceeded bulls and heifers in that order in the proportion of long bones and bulls exceeded steers, late castrates, and heifers in the proportion of flat bones and vertebrae.

## SUMMARY AND CONCLUSIONS

The aim of the study was to define more meaningfully the influence sex had on the growth and development of beef cattle. Record was kept of birth weight, weaning weight, initial feedlot weight, bimonthly feedlot weights and final feedlot weight of four sex groups of animals. Slaughter was performed at three predetermined weights. The left side of the carcass was completely dissected into individual muscles, bones and fat deposits, the right side was cut into boneless closely trimmed retail cuts.

Bulls were consistently heavier at birth than heifers over a 3 year period but only in one year were the differences significant. Differences in weaning weights between bulls, steers (castrated at 2 months of age) and heifers were non significant in 2 years studied. Males were consistently heavier than females but in one year bulls exceeded steers while in the other the reverse was true. It was suggested that a bias may have occurred in the latter case because of health of herd in that year.

Bulls were superior to steers and late castrates which were superior to heifers in post-weaning performance. At the lighter weight bulls and steers significantly exceeded heifers in per day of age production of final live weight, cold carcass weight, total muscle weight and boneless retail weight while at the heavier weights bulls significantly exceeded steers, late castrates and heifers.

With increasing live weight and increasing proportion of fat the proportion of brisket, chuck and retail trimmed fat increased while the proportion of loin, round, ribs and total boneless retail

meat decreased. Some of the differences can be explained on the basis of differential fattening the brisket and chuck increasing rapidly in fat content while the loin, round and ribs increased more slowly while others arise because of differential muscle growth. Differences among sex groups also arise as a result of differential fattening and muscle growth.

As liveweight increased so did the absolute weight of each of the major tissues. Bulls had a greater amount of muscle and bone and a smaller amount of fat than did steers and heifers respectively. Late castrates and steers were not significantly different. Adjustment by covariance to a common weight of muscle plus bone still indicated that heifers had the largest amount of fat followed by late castrates, steers and bulls in that order.

With increasing liveweight of the animal, the proportion of muscle and bone decreased while fat increased. Differences in proportions among sex groups were due to the onset of the fattening stage. Fattening was more rapid in heifers than in steers which in turn showed earlier fattening than bulls. Therefore at similar weights the sex groups would differ in their proportion of the major tissues but composition may be similar if the sex groups contained similar proportions of fat.

Growth of muscle groups is in agreement with the work of Butterfield and Berg (1966b). Changes in proportions of the nine muscle groups with increasing live weight in the animal supports the centripetal growth theory of Hammond (Palsson, 1955). Exceptions were the muscles of the neck which were late maturing and muscles

of the loin which developed uniformly throughout.

With increasing live-weights and proportions of fat there was a differential deposition of fat in the carcass. The proportion of fat in the hindquarter, intermuscular and body cavity deposits decreased while forequarter, subcutaneous and kidney deposits increased. All differences between sex groups in the proportion of fat in the various deposits is explainable in terms of differences in the onset of the fattening stage. Bulls had a greater proportion of fat in the hindquarter, intermuscular and body cavity deposits and a smaller proportion in the forequarter, subcutaneous and kidney deposits than did heifers. Steers and late castrates were not significantly different from each other and were intermediate to bulls and heifers.

With increasing live-weight the proportion of bone in the extremities decreased while the proportion in the flat bones increased. Generally steers and late castrates exceeded bulls and heifers in that order in the proportion of long bones while bulls exceeded steers, late castrates and heifers in the proportion of flat bones.

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